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REPORT NO: 195-C DATE. 4-24-53

TITLE: PULSE-JET HELICOPTER POWER CONTROL SYSTEM DEVELOPMENT

THIRD QUARTERLY PROGRESS REPORT

MODEL NO. — COPY NO. 30

American Helicopter Co. Inc.

CALIF. MESA, ARIZONA

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ENGINEERING REPORT

SECURITY INFORMATION

REPORT NO: 195-C DATE. 4-24-53

TITLE: PULSE-JET HELICOPTER POWER CONTROL SYSTEM DEVELOPMENT

THIRD QUARTERLY PROGRESS REPORT

MODEL NO. COPY NO. 30

CONTRACT NO. AF 33(600)-5860
Supplement No. 4, Items 1(d) and 1(e)
REVISIONS:

EXPENDITURE ORDER: X-506-230

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American helicopter co. inc.
MANHATTAN BEACH, CALIF. • MESA, ARIZONA

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1. SUMMARY

Fuel system and rotor system response rates for a typical pulse-jet helicopter are presented. Calculations relating to a programmed-throttle type power-control system are continued to cover steady state operation over the entire flight range of the helicopter as well as dynamic performance during two typical maneuvers. The excellent results obtained with the programming control in these studies indicates the desirability of its continued evaluation. Power Plant Laboratory approval of the proposed program is requested in order that design, fabrication and testing of this system may be initiated.

Plans for the further study of a "fully automatic" control system and of cyclic fuel injection are outlined.

2. INTRODUCTION

This is the third quarterly progress report describing work performed under Items 1(d) and 1(e) of U. S. Air Force Contract No. AF 33(600)-5860, Supplement No. 4. These items cover the development of a basic power control system for pulse-jet powered helicopters and the investigation of cyclic fuel injection as a means of reducing rotor in-plane vibration and torque variation.

The first report of this series, Ref. 1, contains a general discussion of possible power control configurations for pulse-jet helicopters without reference to a specific model. On the basis of that discussion, it is concluded that some form of programmed throttle actuation with collective pitch change, (with the possible inclusion of a simple governor as a trimmer), is the most attractive possibility.

In the second report of this series, Ref. 2, aerodynamic and power plant performance data for a typical pulse-jet-propelled helicopter are presented and combined into level flight equilibrium charts. A fuel flow vs collective pitch schedule is derived from these charts and a detailed fuel system is proposed to implement this schedule.

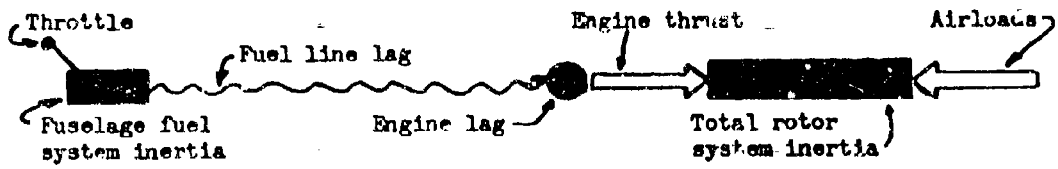
The present report continues the evaluation of the program type control system and outlines a proposed program for the completion of the subject contract items.

3. DISCUSSION

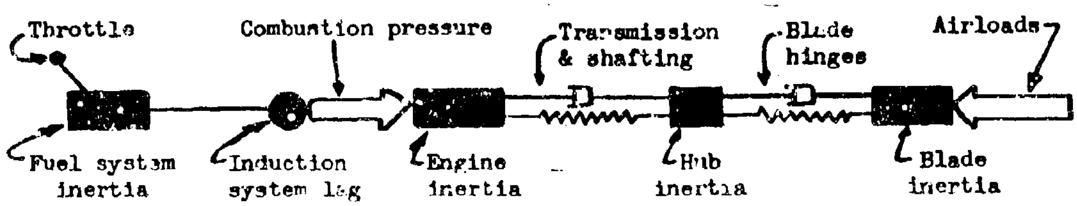
3.1 SYSTEM RESPONSE RATES

The overall response of a typical pulse-jet helicopter to variations in throttle position is markedly different from that of typical shaft-driven or pressure jet helicopters. The system diagrams shown below illustrate the more important differences.

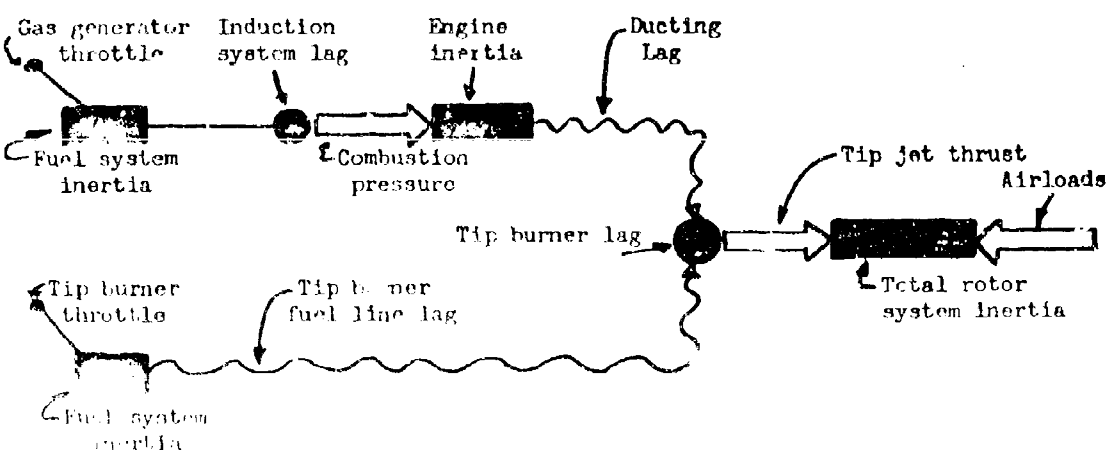
TYPICAL PULSE-JET HELICOPTER ---Diagram A



TYPICAL SHAFT-DRIVEN HELICOPTER ---Diagram B



TYPICAL PRESSURE JET HELICOPTER ---Diagram C



In the shaft-driven helicopter, engine combustion pressure acts on a system of three masses coupled by springs and dampers. The response of such a system to a step input at the throttle is extremely complicated, and an adequate analysis will involve the simultaneous solution of a series of differential equations.

In the pressure-jet helicopter, the jet thrust acts directly on the rotor inertia; but the combined gas generator and tip-jet fuel systems represent a complex problem in coordination and response rate. Changes in rotor power generally involve scheduled changes in both tip-jet fuel and gas generator output; moreover, the gas generator response rate is likely to be slow because of the engine inertia and the long ducts required. Analysis is obviously difficult.

In the pulse-jet helicopter, only one fuel system is required, and the engine thrust again acts directly on the mass of the total rotor system. The response of this system to a step input at the throttle involves only the fuel system lag and the rotor inertia, and an entirely adequate solution may be obtained by a simple numerical integration.

The fuel system and rotor system response rates for a typical pulse-jet helicopter have been determined and are presented in the following paragraphs.

3.1.1 Fuel System Response Rate

In the typical pulse-jet helicopter fuel system of Diagram A, the lag between throttle movement and engine thrust is composed of three effects:

(1) Inertia of the fuselage fuel system (lines, relief valves, etc.)

(2) Lag in the rotor fuel lines (discussed in detail in Ref. 2, page 8).

(3) Lag in engine thrust response to fuel flow changes (being investigated under cyclic fuel injection study).

Since both engine thrust and engine noise are functions of the pressure wave action within the engine, it is assumed that engine noise level is an accurate indicator of instantaneous engine thrust. On the basis of this assumption, an experimental evaluation of overall fuel system lag has been performed and is summarized in Fig. 1. The results shown indicate that about 2.0 seconds are required for the engines to reach stabilized operation following a rapid change of throttle position. This value of overall system lag is in close agreement with the 2.1 second rotor fuel line lag calculated in Ref. 2, which suggests that the fuselage fuel system and engine thrust lags may be negligible. Further investigations of the response of modified systems are planned; however, the present results are considered to represent the overall performance of the basic XH-26 system. The responses to step throttle changes of various magnitudes were measured, and the effect of step magnitude on lag time was found to be negligible.

3.1.2 Rotor System Response Rate

In the typical pulse-jet powered helicopter, the absence of primary power transmission through the hub results in the selection of a teeter-mounted, rigid rotor. Since blade airloads, engine thrust and rotor inertia are concentrated at, or near, the blade tips, blade chordwise elasticity can be neglected; and the entire rotor system inertia can be taken as a lumped constant as illustrated earlier in Diagram A. As a point of interest, the engines and associated attachment fittings constitute approximately one-half the total rotor system inertia on the XH-26.

The rotor system response rate of the XH-26 is presented in Fig. 2 as a family of tip speed time histories for various increments of pulse-jet thrust above or below the amount required for stabilized operation at the instantaneous tip speed. A typical conclusion which may be drawn from this figure is that ±10 lb/eng. thrust error, (about 25% of the rated engine thrust), can exist for about 2.3 seconds without the rotor tip speed exceeding the ±5% steady state error specified in Ref. 1; moreover, this same thrust error can exist for more than 5 seconds without causing the tip speed to exceed the +10, -20% transient error tolerances.

Results obtained from Fig. 2 are highly conservative, since in actual flight any error in engine thrust is reduced as the tip speed changes. In fact, for most reasonable errors in throttle setting, the power available and power required curves will intersect before dangerous speed errors are encountered. This stabilizing effect will be discussed further in the following paragraphs.

3.2 PROGRAMMED FUEL CONTROL SYSTEM

The analyses reported in this section are considered to complete the study phase of the programmed throttle fuel control system. Fuel flow vs collective pitch schedules have been obtained for all normal operating conditions of the helicopter; the dynamic behavior of the helicopter with the program type control installed has been calculated for two typical maneuvers; and the power control specification has been amended to define the detail requirements for a prototype system for XH-26 flight tests.

According to the work statement of the subject contract, the expenditure of funds and effort shall not exceed that required for satisfactory completion of the study phase until approval has been given by the Chief, Power Plant Laboratory, Wright Air Development Center. Upon receipt of such approval, design, fabrication and testing of a programmed throttle control system will be initiated.

The altitude compensating element of the control system will be subcontracted to a competent manufacturer (one satisfactory proposal has already been received). The remainder of the system will be fabricated by the American Helicopter Co., Inc., using standard components wherever practicable. The altitude element, which will be the most expensive component of the system, will be immediately applicable as a rich and lean limit control for a governed throttle system if subsequent comparisons indicate the desirability of such a system.

3.2.1 Schedule Refinement

The preliminary fuel flow vs collective pitch schedules of Ref. 2, Fig. 9, have been revised and extended to cover the entire operating range of the typical pulse-jet helicopter (XH-26). The revised schedule is presented in Fig. 3 of the present report. The normal, or detent, position of the programming cam has been selected to embrace the maximum number of operating conditions. With the cam in the detent, the helicopter can be flown through many maneuvers without pilot trimming and without excessive errors in rotor speed. For certain extreme maneuvers, the cam may be shifted slightly as indicated by the dashed position; however, the rotor inertia is sufficient to prevent rapid changes in rotor speed and leisurely pilot action will suffice.

Although a definite answer is precluded by the approximations involved in the calculations, it is entirely possible that the helicopter can be flown throughout its operating range with the cam in the detent without encountering dangerous rotor speed errors. If this possibility is substantiated by flight test data, there will be little question that the programmed throttle system is optimum for helicopters of this type.

3.2.2 Dynamic Performance

Dynamic performance calculations for the programmed throttle control installed in the XH-26 helicopter during two maneuvers are reported in Ref. 3 and are summarized herein.

3.2.2.1 Horizontal Pull-up - Four horizontal pull-ups (rapid transition from forward flight to hovering flight) are analyzed in Fig. 4. For the first case, the fuel system lag is taken as 1.5 seconds (from Fig. 1) and forward speed is reduced to zero in 10 seconds. Even though the programming cam reduces throttle fuel flow to the lean limit value at t=0, the 1.5 second lag between throttle and engines is sufficient to cause intolerable overspeed within 2 seconds. This result indicates clearly the necessity for reducing fuel system lag, since only by means of anticipatory throttle movement by the pilot can the helicopter be flown safely through this maneuver with the present fuel lag time.

Acting on the assumption that the fuel system lag time can be reduced to 0.5 seconds, cases 2 and 3 are shown for 5 second and 10 second pull-up times. In each case, the maximum rotor transient overspeed is less than 10%, and the final equilibrium tip speed is only 3% below the nominal value of 425 fps.

To complete the evaluation of fuel system lag time, case 4 was prepared using zero lag and 10 second pull-up time. This case is identical with 3 except for the lag time, and it is interesting to note that the maximum overspeed is not appreciably affected by this 0.5 second change in lag time.

During the first portion of a horizontal pull-up, the programming control has perfect action since it reduces throttle fuel flow to the lean limit value at the instant that collective pitch is lowered to zero. The pulse-jet engines acctually produce negative thrust during the first portion of the maneuver and the resultant rotor overspeed is caused by autorotational air forces on the rotor. A governor type control must have extremely rapid response to speed errors if it is to provide satisfactory throttle control during this maneuver.

In view of the fact that a perfectly responding control and a zero lag fuel system will allow the rotor speed to be outside the ±5% steady state tolerance band for approximately 8.5 seconds during a horizontal pull-up, it appears reasonable to modify the tentative control specification (Ref. 1, page 4. Item 3.2.3) to allow excursions beyond the ±5% band for periods up to 15 seconds.

In spite of the rotor speed variations shown, the pulse-jet helicopter gives an excellent account of itself in the horizontal pull-up as compared with a typical shaft driven helicopter with its low rotor inertia and orverrunning clutch. In shaft driven helicopters, it is frequently impossible to perform this maneuver without gaining altitude and/or causing the rotor to unclutch and overspeed.

3.2.2.2 Descending Pull-up - Four descending pull-ups (transition from forward descent to hover) are described in Fig. 5. In all cases, the initial rate of descent is 500 fpm; the variables are transition load factor and presence or absence of ground effect during hovering. The 0.5 second fuel system lag found necessary for satisfactory performance of the horizontal pull-up was used through these calculations; it is felt that a

lag time of this magnitude can be achieved by the means outlined in Ref. 2, page 8.

Although this maneuver appears more violent than the horizontal pull-up and probably does call for more rapid adjustments of collective and cyclic pitch, it turns out to be less demanding on the fuel control system. There is no tendency for the rotor to overspeed with the programming control. Moreover, even if the cam is left in its original position (see Fig. 3) and the final hover is outside the groundeffect, the stabilized tip speed is less than 15% below the nominal value and can be corrected at the pilot's convenience by the simple expedient of placing the cam in its normal detent.

As a result of these studies, it is apparent that the response rate described in the preliminary specification, Section 3.2.4 of Ref. 1, is based on an unfortunate choice of maneuvers. A more adequate response rate requirement based on the horizontal pull-up has been incorporated in the revised specification.

3.2.3 Revised Control System Specification

The preliminary power control system specification of Ref. 1 has been revised to incorporate previously mentioned error and response rate limits and to reflect comments received from the Power Plant Laboratory at Wright Air Development Center. The revised specification is included as Appendix B to this report.

3.3 "FULLY AUTOMATIC" CONTROL SYSTEM

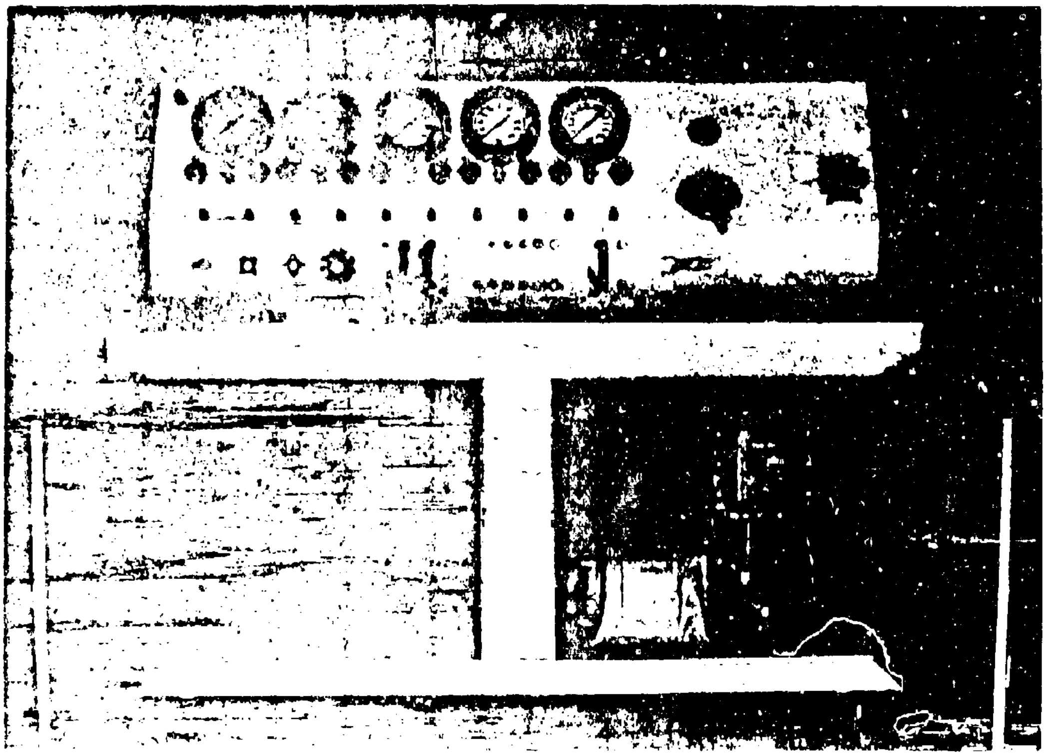
The final selection of an optimum power control system for pulse-jet helicopters will involve consideration of factors such as reliability, accuracy, cost and weight. The design characteristics and intended function of a given helicopter model may affect the choice of control systems, and it would be most unusual if a single system proves to be optimum for all applications.

The programmed throttle control obviously warrants continued development because of its simplicity, stability, and apparently adequate accuracy. However, it also appears desirable to evaluate the potential performance of a more elaborate system, even though such a system may not be indicated for a simple helicopter like the XH-26. For the purpose of this study, a requirement has been established for a control system which requires the minimum amount of pilot attention, even though such a system may involve considerable complexity. This is termed the "fully automatic" system.

The "fully automatic" control system study will be primarily concerned with the incorporation of some form of speed governor; however it will also include consideration of items such as automatic engine start sequencing and automatic engine thrust maximizing. It is the intent of this Contractor to subcontract at least that portion of this work which is associated with the speed governor; therefore, four competent organizations active in the automatic control field have been invited to submit proposals. A summary of the proposals received as well as a recommended course of action on this program will be forwarded to Wright Air Development Center following receipt of replies from the organizations contacted.

3.4 FUEL FLOW BENCH

The fuel flow bench has been completed and has been checked out on tests of fuel pumps, relief valves, throttles, accumulators, and other fuel system components. A photograph of the bench is included below; a schematic diagram of the bench may be found in Ref. 1, Fig. 1



3.5 CYCLIC FUEL INJECTION

Tests to obtain the additional basic power plant data required for a conclusive analysis of cyclic thrust effects on helicopter performance are currently in progress. The specific quantities being determined are:

(1) variation of pulse-jet thrust with yaw angle, and

(2) response of the pulse-jet engine to rapidly varying fuel flow.

Using results of these tests, analytical work will be continued to define: (1) the extent of rotor in-plane vibration and torque variation associated with constant fuel flow to tip-mounted, pulse-jet engines during forward flight, and (2) feasibility of, and techniques required for, minimizing these effects through cyclic fuel injection.

Preliminary considerations of the mechanical aspects of cyclic fuel injection have suggested that cyclic valves at the rotor tips may be used in conjunction with the cavitating rotor type fuel system currently planned for the programmed throttle power control system. With this arrangement, the rotor hub fuel flow would be controlled to match the average power requirement, and the instantaneous fuel flow to the engine would be modulated as required for minimum vibration. This modulation might be controlled by the cyclic motion of the pulse-jet longitudinal axis relative to the rotor blade tip chord for free-swiveled engines. For rigidly mounted engines, the modulation might be controlled by instantaneous pitot pressure at the rotor tip; or, of course, swiveling vanes could be mounted at the rotor tip to duplicate the valve actuating function of swivel mounted engines.

4. CONCLUSIONS AND RECOMMENDATIONS

The work reported in this report is considered to complete Item 1d (1) of the subject contract as it affects the programmed throttle power control system. Design, fabrication, and testing of this system under Items 1d (2), (3), and (4) will be initiated upon receipt of approval by the Chief, Power Plant Laboratory, Wright Air Development Center. The design and fabrication of the altitude compensating unit for this systme will be subcontracted to a competent organisation.

Study of a "fully automatic" control system incorporating a speed governor will be continued, with the services of a subcontractor being utilized to the maximum extent possible. A detail program for this study will be presented to WADC upon receipt of the proposals which have been solicited from several control companies.

5. REFERENCES

Ref. 1: American Helicopter Co., Inc. Report No. 195-A, "Pulse-Jet Helicopter Power Control System Development - First Quarterly Progress Report", R. W. McJones, 1 February 1953.

Ref. 2: American Helicopter Co., Inc. Report No. 195-B, "Pulse-Jet Helicopter Power Control System Development - Second Quarterly Progress Report", R. W. McJones, 1 March 1953.

Ref. 3: American Helicopter Co., Inc. Report No. 195-C-1, "Analysis of a Programmed Throttle Power Control System for a Typical Pulse-Jet Helicopter", L. R. Gutstadt, to be published.

APPENDIX A

Nomenclature

Symbol	Definition	Dimensions
A	Rotor Disk Area - πR^2	Ft^2
C_P	Rotor Power Coefficient, $\frac{P}{\rho A(\Omega R)^3}$	Dimensionless
C_T	Rotor Thrust Coefficient, $\frac{T}{\rho A(\Omega R)^2}$	Dimensionless
f	Helicopter Equivalent Parasite Drag Area	Ft^2
F	Engine Net Thrust	Lbs.
g	Gravitational Acceleration	Ft/sec/sec
h	Altitude above Sea Level	Ft
I_{rotor}	Rotor System Inertia	Slug Ft^2
Q	Torque	Lb.Ft.
R	Rotor Radius	Ft.
t	Time	Seconds
T	Rotor Thrust or Lift	Lbs.
V	Forward Flight Velocity	Ft/sec
V_c	Vertical Flight Velocity	Ft/sec
V_T	Rotor Tip Speed = ΩR	Ft/sec
W	Gross Weight	Lbs.
W_f	Fuel Flow Rate	Lbs/hr
Z	Distance of Rotor above ground Plane	Ft
δ	Ratio of Atmospheric Pressure to Standard S. L. Pressure	Dimensionless
Ω	Rotor Angular Velocity	Radians/sec

Symbol	Definition	Dimensions
θ_0	Rotor Collective Pitch	degrees
ρ	Atmospheric density	$Slug/Ft^3$
σ_a	Ratio of Atmospheric Density of Standard S. L. Density	Dimensionless
σ_s	Rotor solidity = $\frac{\text{Planform Area}}{\text{Disk Area}}$	Dimensionless
μ	Advance Ratio = $\frac{\text{Forward Speed}}{\text{Tip Speed}}$	Dimensionless

APPENDIX B

PRELIMINARY CONTROL SPECIFICATION

1. INTRODUCTORY COMMENTS

This specification sets forth the characteristics desired in a power control system for pulse-jet-powered helicopters. Revisions will be made from time to time during the course of investigations performed under the present contract with the goal of defining an optimum control system considering performance, weight, reliability, and other parameters. (Items in parentheses apply to the prototype system for XH-26 flight tests.)

2. CONTROL PERFORMANCE REQUIREMENTS

2.1 GENERALIZED PERFORMANCE REQUIREMENT

The control shall relieve the pilot of the task of coordinating engine fuel flow with changes in power required. Ideally, the control will correct for all changes in flight path, gross weight, altitude, etc., without adjustment by the pilot. If necessary, a compromise system will be considered wherein the pilot may be called upon to perform "trimming" adjustments; however, any such adjustments must be small enough that they will require only occasional attention on the part of the pilot.

2.2 ENGINE FUEL FLOW

The control system must maintain engine fuel flow between the lean and rich blow-out limits at all altitudes within the design operating range of the helicopter. At the same time, it should permit attainment of maximum thrust and throttling ranges. On the basis of the operating characteristics of current pulse-jet engine, tolerance bands of ±10% can be established for both maximum and minimum specified fuel flows without risking blowout and without significatn reduction in maximum thrust or throttling ranges. (For the XH-26, the nominal rich and lean limits are at approximately .. W_f = 240 and 120 lb/hr/engine respectively.)

2.3 ROTOR SPEED REGULATION

Steady state regulation of the rotor rpm shall be maintained within ±5% of the specified value for all operating conditions of the helicopter

During abrupt maneuvers, transient variations of rpm as great as +10% and -20% will be tolerated provided that no excursion beyound the ±5% band persists for longer than fifteen seconds.

2.4 RESPONSE RATE

The response rate shall be adequate to provide the speed regula-

tion of Section 2.3 above. (For the XH-26, it is estimated that the throttle actuator must reach its full travel within 0.1 seconds after the application of a maximum change in collective pitch.)

2.5 STABILITY AND DAMPING

The system shall be both statically and dynamically stable. Any oscillatory transients, if present, must be damped sufficiently to provide a decay rate equal to that of a simple one degree of freedom system with 30% of critical damping.

2.6 CHECK OUT PROVISIONS

The control system shall be designed so that its proper operation can be assured during ground operation before take-off.

3. CONTROL PHYSICAL REQUIREMENTS

For purposes of weight and power specification, the control system shall be defined as consisting of all components over and above those required by a simple manually control fuel and collective pitch system.

3.1 CONTROL SYSTEM WEIGHT

The control system weight shall not exceed 1/2% of the maximum hourly fuel consumption of the helicopter for which it is designed. (The XH-26 system shall not weigh more than 2.4 lbs.)

3.2 CONTROL POWER EQUIPMENT

The control system shall not require more than ½% of the maximum helicopter rotor horsepower. The control shall not rely on the helicopter system for hydraulic or electrical power. (The XH-26 system shall not require more than 0.2 horsepower.)

4. MISCELLANEOUS REQUIREMENTS

The control system shall be capable of satisfactory operation over the entire atmospheric and operational range specified for the helicopter for which it is designed. (For XH-26; Altitude =S.L. to 10,000 ft, Temperature = 0° to 120° F.)

4.2 STORAGE AND HANDLING

The control system shall be designed and constructed so that it may be stored, shipped, and placed in operation without special packing or adjustment procedures.

4.3 MAINTENANCE

Field main[illegible] procedures shall be simple and shall not [illegible]. Any component shall be

replaceable in the field by a semi-skilled mechanic using standard tools.

4.4 FUELS

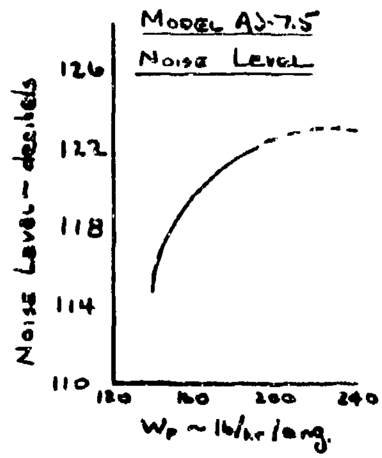
The power control system shall be designed to operate with aromatic fuel as defined in Specification AN-F-42.

MODEL XH-26

FUEL SYSTEM RESPONSE RATE

A. PRINCIPLE - Engine noise is an accurate indicator of engine thrust.

Curve at right shows noise level in cockpit as function of stabilized engine fuel flow. (Noise below 1200 cps filtered out.)



B. TECHNIQUE -- Apply filtered output of noise measurement amplifier to "Brush" recorder. Apply signal from switch on throttle to "Brush" event marker. Pilot stabilizes fuel flow at 140 lb/hr/eng. and suddenly opens throttles; after engines stabilize at new value, pilot suddenly closes throttles.

C. RESULTS - Trace below indicates that significant change in engine output begins about 1.0 second after throttle movement, and stabilized operation is obtained in about 2.0 seconds.

For purposes of dynamic control response calculations the effective fuel system lag is taken to be 1.5 seconds, since the noise level is nearing its equilibrium valve at this time.

Similar traces obtained for smaller increments of throttle movement indicate that the lag time is essentially independent of the magnitude of the throttle movement.

D. TRACE - Oscillograph trace of engine noise level and throttle motion.

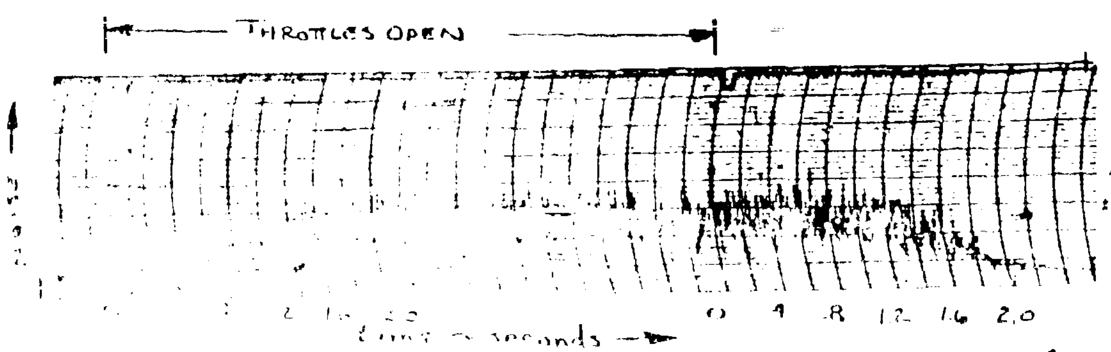


FIGURE 1.

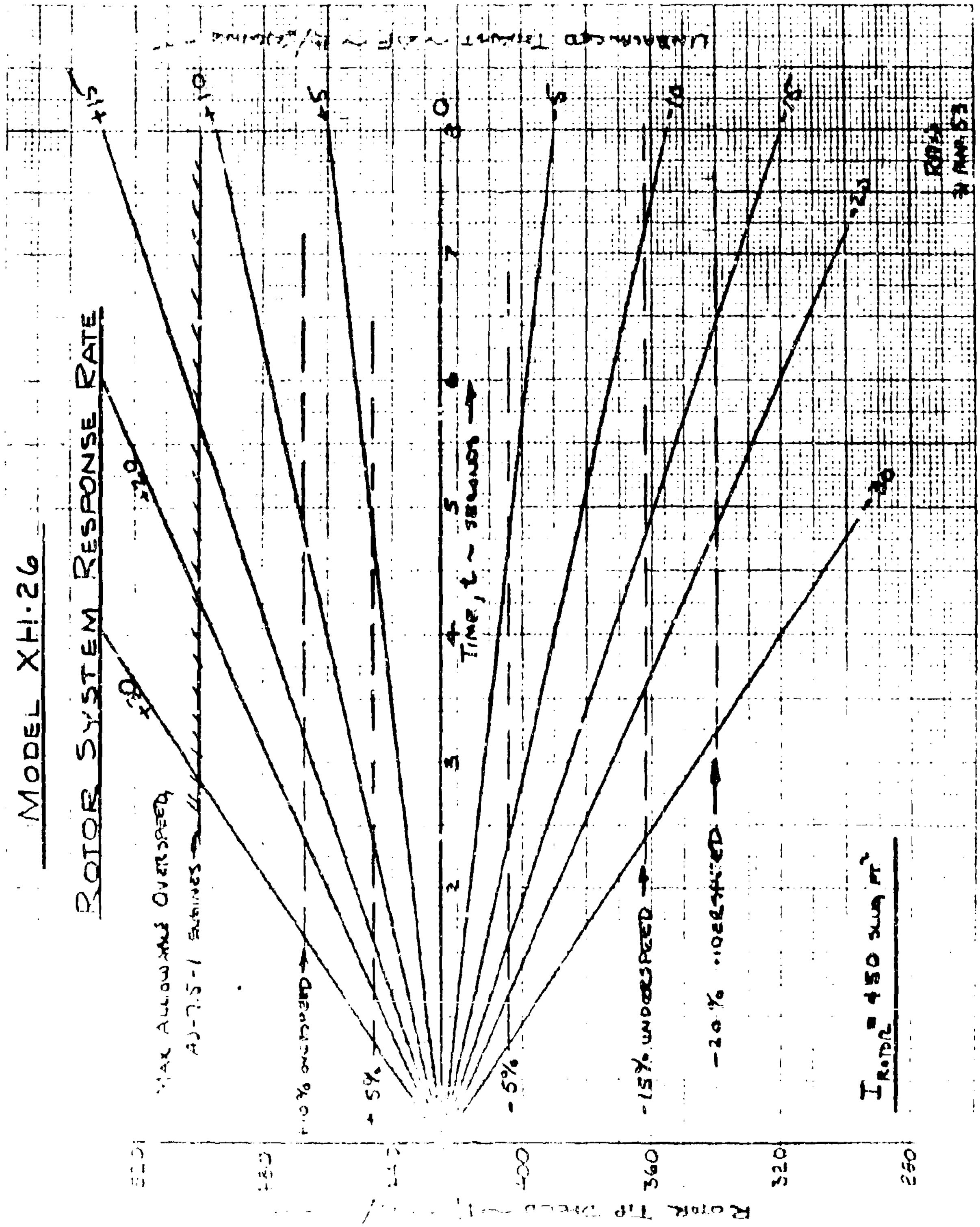

MODEL XH-26
ROTOR SYSTEM RESPONSE RATE
MAX ALLOWABLE OVERSPEED XJ-7.5-1 ENGINES
+10% OVERSPEED
+5%
-5%
-15% UNDERSPEED
-20% UNDERSPEED
TIME, t ~ SECONDS
I_{ROTOR} = 450 SLUG FT²
ROTOR TIP SPEED
+15
+10
+5
0
-5
-10
-15
-20
-25
-30
+20
+25
+30
360
320
280

FIGURE 2

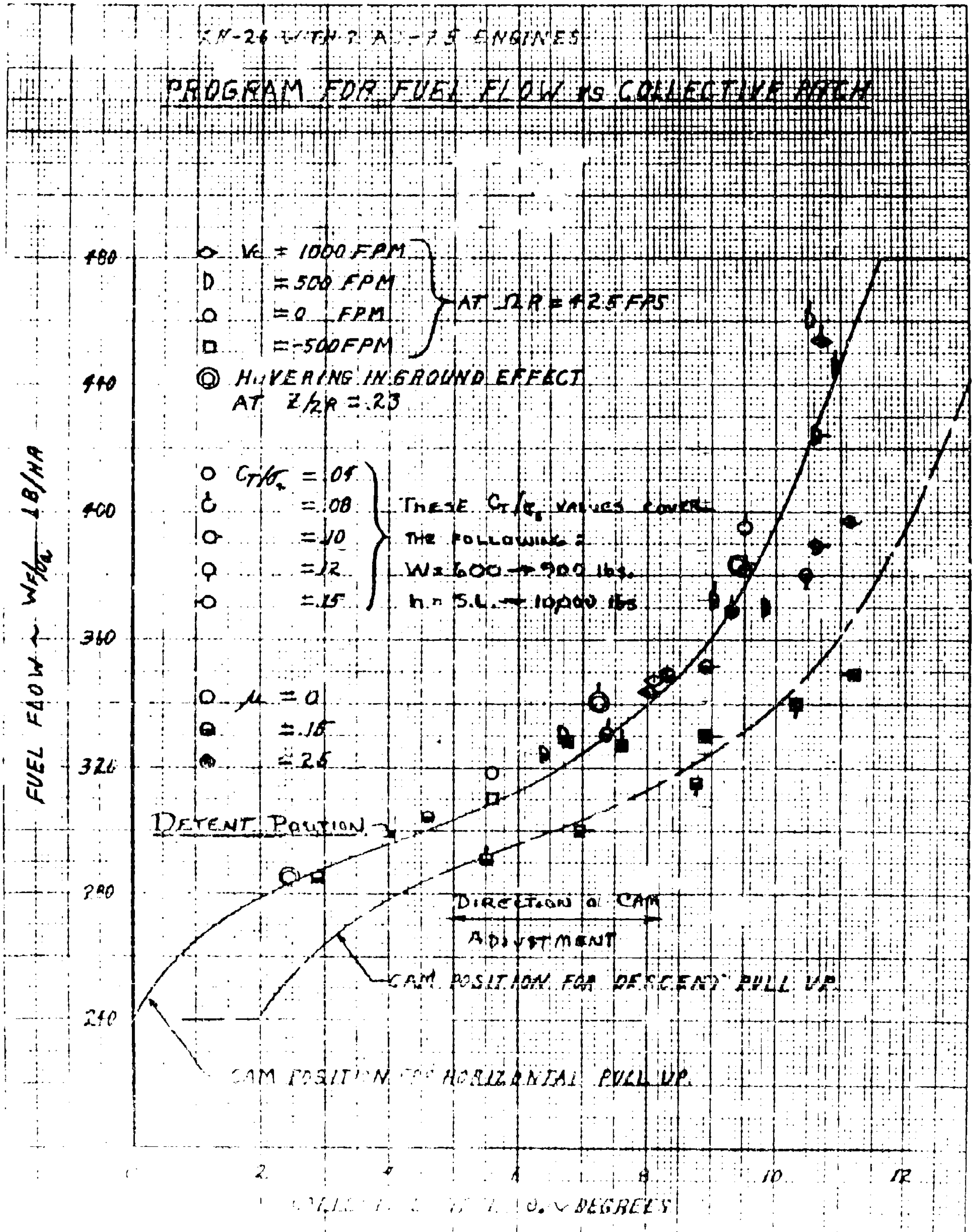

PROGRAM FOR FUEL FLOW vs COLLECTIVE PITCH
Vc = 1000 FPM
= 500 FPM
= 0 FPM
= -500 FPM
AT ΩR = 425 FPS
HOVERING IN GROUND EFFECT
AT Z/2R = .23
CT/σ = .04
= .08
= .10
= .12
= .15
THESE CT/σ VALUES COVER
THE FOLLOWING:
W = 600 → 900 lbs.
h = S.L. → 10000 lbs
μ = 0
= .15
= .25
FUEL FLOW ~ WF/δ LB/HR
480
440
400
360
320
280
240
DETENT POSITION
DIRECTION OF CAM
ADJUSTMENT
CAM POSITION FOR DESCENT PULL UP
CAM POSITION FOR HORIZONTAL PULL UP
2
4
6
8
10
12
DEGREES

FIG 3

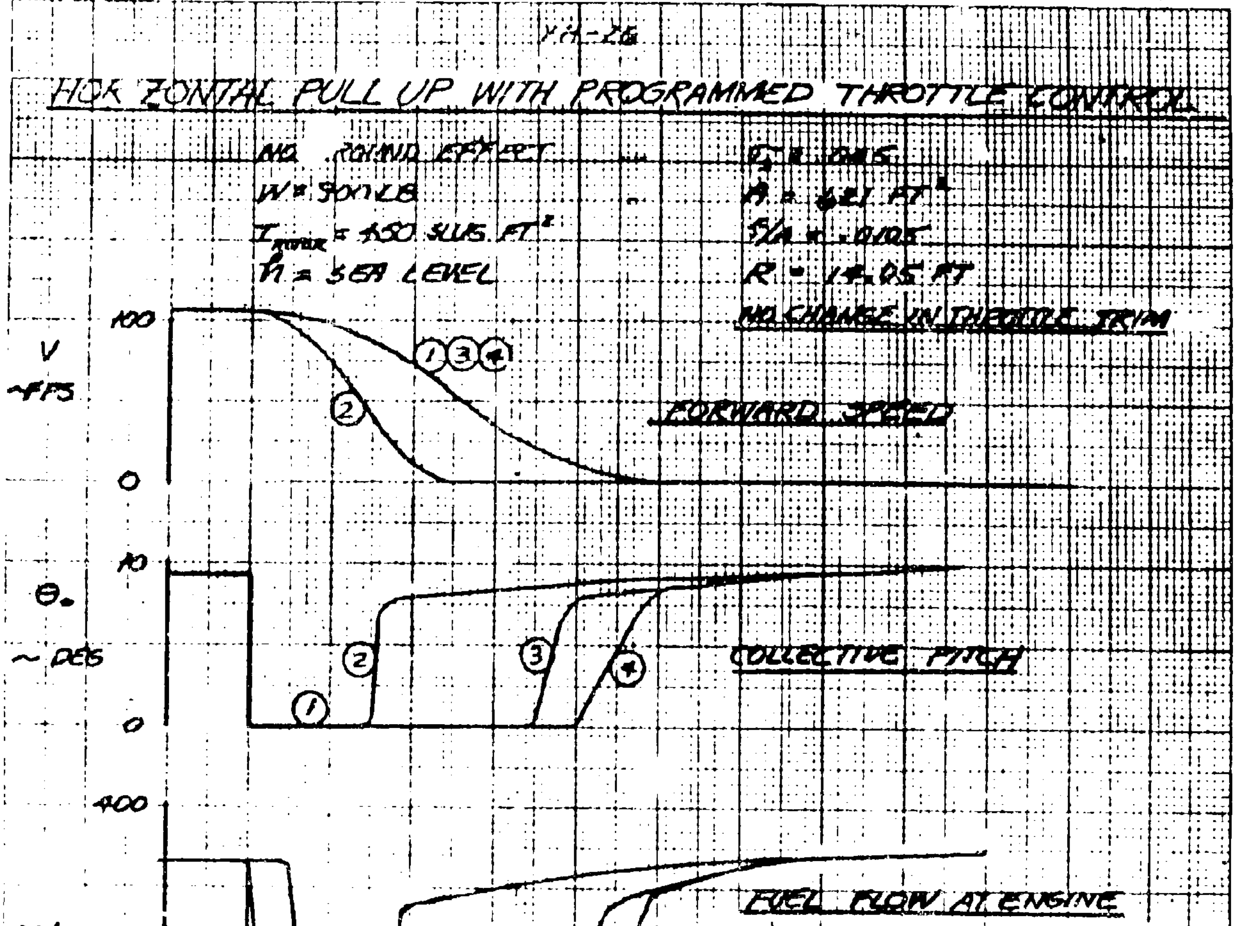

YH-26
HORIZONTAL PULL UP WITH PROGRAMMED THROTTLE CONTROL
NO GROUND EFFECT
H = SEA LEVEL
R = 14.05 FT
NO CHANGE IN THROTTLE TRIM
V ~FPS
FORWARD SPEED
θ ~DEG
COLLECTIVE PITCH
W_F ~LB/HR
FUEL FLOW AT ENGINE
TIP SPEED
① FUEL FLOW LAG = 1.5 SEC PULL UP TIME = 10 SEC
② FUEL FLOW LAG = .5 SEC PULL UP TIME = 5 SEC
③ FUEL FLOW LAG = .5 SEC PULL UP TIME = 10 SEC
④ FUEL FLOW LAG = 0 PULL UP TIME = 10 SEC
100
0
10
0
400
300
200
490
470
12
16
20

Figure 4

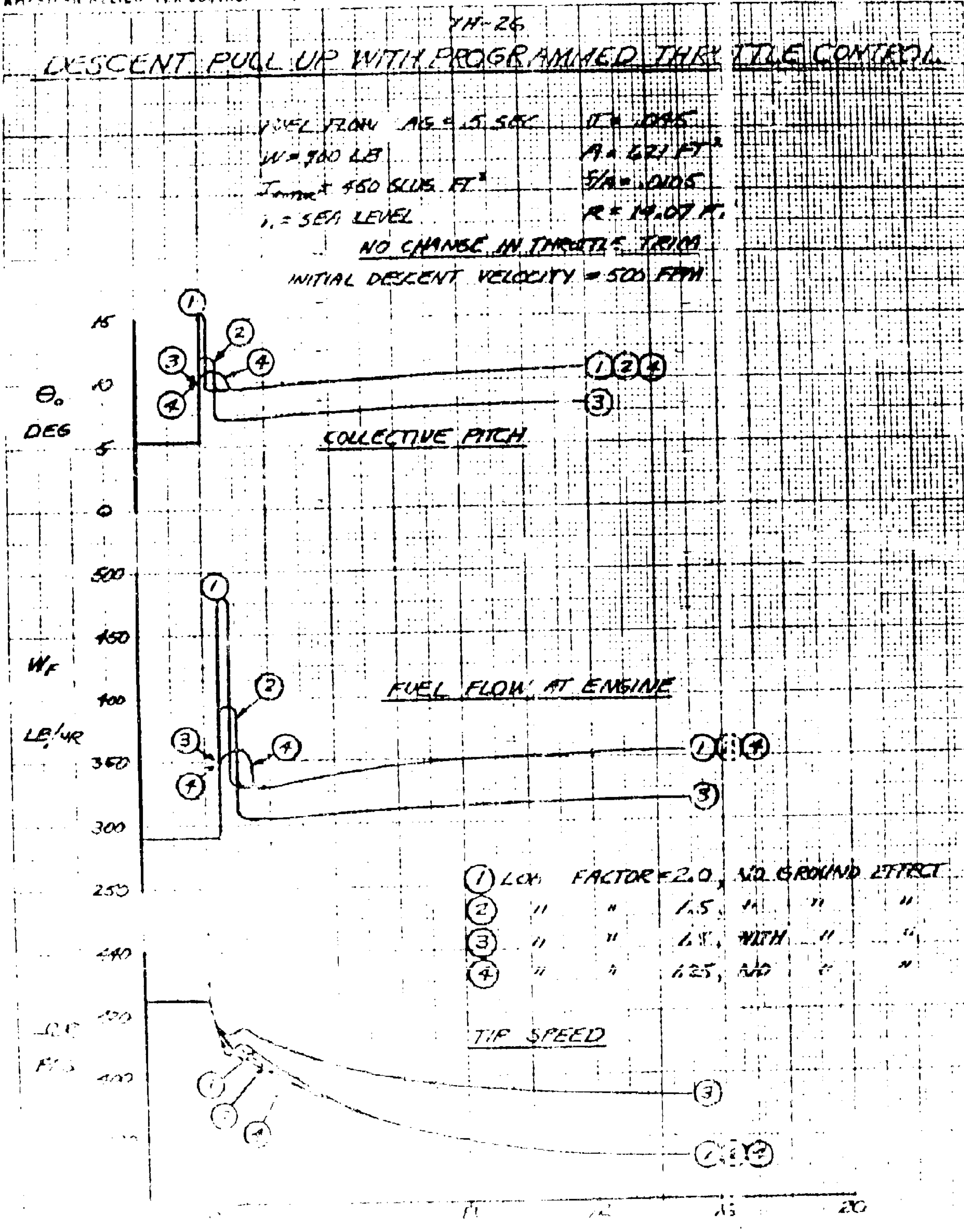

YH-26
DESCENT PULL UP WITH PROGRAMMED THROTTLE CONTROL
FUEL FLOW AG = 15 SEC
W = 700 LB
I = 460 SLUG FT²
= SEA LEVEL
A = 621 FT²
R = 14.07 FT
NO CHANGE IN THROTTLE TRIM
INITIAL DESCENT VELOCITY = 500 FPM
θ₀ DEG
COLLECTIVE PITCH
W_F LB/HR
FUEL FLOW AT ENGINE
TIP SPEED
(1) LOAD FACTOR = 2.0, NO GROUND EFFECT
(2) " " 1.5, " " "
(3) " " 1.5, WITH " "
(4) " " 1.25, NO " "
15
10
5
0
500
450
400
350
300
250
20

FIGURE 5